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Efficiency of Solar Energy Devices: Cause and Concern

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ABSTRACT

The present experimental study carried out in the Manali town, where all the solar panels positioned on a fixed surface with its face towards south at an elevation angle of 45°. They do not track the Sun and therefore, the efficiency of power generation is low. We proposed two axis solar tracker to ensures the maximum conversion of solar energy into electricity. Experimental investigation shows that using solar tracker the power generation can be increased by 45% as compared to a fixed PV module. The proposed measurement system provides a valuable contribution to the technologists who are working on the development of tracking systems in the solar energy technology field. The results obtained on the experimental site achieved a 53.8 % gain in energy production, which reveals that the solar tracking system is able to deliver high power and a better conversion efficiency compared to a fixed module inclined 45° at the same latitude.

Keywords: Solar flux; sunshine hours; photo voltaic module; solar tracker.

1. INTRODUCTION

The increasing demands of the conventional sources of energy and increasing the level of pollution is of great concern[1]. Moreover, these sources of energy are limited and depleting with the rapid rate[2]. All these facts, making the attention of the worldwide scientists to explore, harness and conserve new sources of energy. Among these the exploration of solar energy is of most concern. Because it is clean, freely available and largest source of energy. The solar energy incident on the horizontal

surface of the Earth in an hour is approximately equal to 5000 times of the total consumption of the global energy by means of all sources in a year[3]. Thus, solar energy has the great potential to ensure an important part of the energy needs in the future[4]. In 1970s the world has to face with the oil crises as a result of this the oil prices increased rapidly. This led the world to enter in the new era, several countries started work to explore the solar energy and conservation of conventional resources for future needs[1,5]. The efforts in this direction are underway to harness solar energy by mean of developing solar energy devices.

Nowadays photo voltaic (PV) cells are gaining much popularity for converting solar energy into electrical energy[5]. According to International Energy Agency (IEA) report, the global efforts in capacity building of photo voltaic technology have been increasing with a growth rate of 40% per year[6]. The conversion of solar light into electrical energy is not a difficult task for the engineers, but the efficiency improvement of the photo voltaic cells is still a challenging one. According to the Physical law to get highest conversion efficiency, the Sun rays must fall at right angles to solar panel surface. The Sun orientation is changing continuously as a result of this the incident radiation on a solar panel is continuously changing. This is the main cause of failure in term of solar panel efficiency rate. In order to maximize power output from the solar panels, one needs to keep the panels aligned with the Sun. In this context, for maximal energy efficiency of a solar panel, it is necessary to have it equipped with a solar tracking system[5,7]. A single axis solar tracker can increase the annual power output energy by 30%, by using the application of two axis it may be achieved up to 36-50%[8,7]. The study conducted over Algeria reports that a single-axis tracking system has increased the efficiency between 30 and 42% in comparison to fixed one and the two axis between 39 and 54%[9]. Huang and Sun[10] conduct the experimental work over Taiwan region and found that by using solar tacking device one can increase the power generation by 25% in relative to a fixed PV module. But, these results can vary with geographic latitude of the location and their climatic conditions. So, the experimental investigation of these solar tracking devices at regional scale becomes essential, particularly from the Himalayan region. This would be an effective approach before to know the efficiency of solar devices, because the costs of solar trackers are much higher than that of fixed modules.

We conduct this study in the Manali town in the northwestern part of Indian Himalaya, where all the solar PV panels are fixed with its face towards south at an elevation angle of 45^{o}. As the Sun is a moving object and this approach is not the best method to harness solar energy[4]. Since the fixed-type solar panel cannot obtain the maximum power output. One of the solutions was to develop a solar tracking device. Here we proposed two axis solar tracker devices.

The present study carried out under three major objectives: (1) to identify the problem and issues in the use of solar energy devices by conducting survey, (2) to find the solution of problem by designing the sun tracking solar system, (3) to analyze experimentally the performance of the sun tracking solar system. However, the reported

results are on the short-term experimental observation. This study highlights that by popularizing the use of solar energy we can solve a part of energy demand and can reduce the dependency on non-renewable sources.

2. EXPERIMENTATION AND OBSERVATION

To meet out the objective, we completed this study in five steps:

Step I: In the first step we conduct observational studies to know the status of sunshine hours and total incoming solar flux. For this we install a Pyranomenter in the campus of Government Senior Secondary School Manali.

Step II: To find the local problem and issues faced by the people in the utilization of solar energy devices was our next step. For this we conduct surveys through a well structure questionnaire.

Step III: To find a solution to the problem and designing of the instrument was our next task.

Step IV: In the fourth step we conduct an experimental investigation using two identical solar PV module.

Step V: Economic feasibility in term of efficiency of the designed instrument was our last step.

3. RESULTS AND DISCUSSION

3.1 Pattern of Sunshine Hours and Solar Flux

One of the main failure causes of solar energy devices is lack of sunshine hours and insufficient amount of solar input. So, to know the status of total sunshine hours and total incoming solar flux we install a Pyranometer in the campus of Government Senior Secondary School Manali. The data recorded after the interval of one hour from morning to evening. Figure 1(a, b) is showing the status of daily pattern of sunshine hours and solar flux. During the observation period in average the sunshine hours recorded 5 hours per day. The average value of solar flux obtained to be 352 Wm^{-2}. These results confirm that the Manali town receive sufficient amount of solar energy, what is expected to run solar energy devices.

3.2 Problem and Issues

To find the problem faced by the user of solar energy devices was our next target. For this we plan to conduct a survey through a well structured questionnaire with special focus on hospitality sector. After conducting survey it come to know that in average a hotel needs about 30 unit energy per day. However, 70% hotelier have installed PV module. But they are not capable to fulfill their current energy demands. The major problem with solar panel technology was its poor efficiencies and higher costs.

3.3 Solution to the Problem

In earlier section we discuss that Manali town receive sufficient amount of solar input what is expected to run solar energy devices. Then why solar energy devices in the region are getting failure. To know the cause of their failure and thereafter to find solution was one of the challenging tasks. During survey campaign, we come to

know that in the Manali town, all the solar panels are fixed with their face towards south at a fix elevation angle of 45^o. As the Sun is moving object and continuously changing its position. For example from morning to evening and with seasons, as a result of this the incident radiation on a solar panel is continuously changing. According to the physical law to get maximum efficiency, the Sun rays must fall at right angles to the surface of the solar panel. The fixed-type solar panel cannot obtain this and this was the main cause of failure of solar energy devices. In order to obtain maximum output from the solar panels one of the solutions was to design a solar tracking device.

3.4 Designing of the Sun Tracking PV Module

As we know that Earth revolves around the Sun in an elliptical orbit as a result of this the solar zenith angle i.e. an angle between zenith and incident solar radiation vary accordingly. During summer, autumn and winter at present experimental site all the solar panels should be tilted at an angle of 10^o, 30^o and 55^o respectively. In Manali town all the solar panels are fixed at an elevation angle of 45^o. So, for optimizing maximum output from the PV module this was not a good approach. To optimize maximum output, we design a simple two axis solar tracking PV module with an additional PV module to run the motor. Figure 2 is showing our designed mechanism of solar tracking system. The one axis allows the panels to give required orientation to keep their face always towards the Sun. The second axis allows the panel to give required elevation angle. The suggested tracker can be designed in simple structure at low cost.

3.5 Experimental Investigation

The experimental investigation was carried out in the campus of Government Senior Secondary School Manali, in order to compare the performance of the solar tracking PV module with a fixed PV module of the same type. An experimental setup was carried out for solar panels of capacity 50 Watts. The two PV panels will be subject to the same solar flux conditions in the same time and the energy output of each panel is monitored and compared. Data registered hourly by using voltmeter and ammeter. The experimental measurements were carried out in various meteorological conditions.

3.5.1 Comparison Between Static Solar Panel and Solar Tracking System

The results obtained through both the module are tabulated in Table 1. From static solar panel, the daily average values of voltage, current and power obtained 10 V, 1.8 A and 22 W respectively. Whereas, from solar tracking system, the respective values were 11 V, 2.8 A and 32 W. Figure 3 (a,b) is showing the comparison of electric power characteristic. From the experimental investigation, we concluded that the gain in power production by using solar tracking PV module increase by 53.8%.

3.5.2 Comparison Between Solar Tracking System Without Reflector and With Reflector

In order to increase the power generation, we further add a simple reflector on the PV module to build a concentrator PV. An experiment was conducted on very clear day. To see the difference in the results, simultaneously we conduct another test using the same PV module without reflector. Experimental investigation shows

that at good condition the PV module with reflector can increase the gain by 16.6%. The total solar power generation increases by 12% for PV with reflector as compared to solar tracker system without reflector. The comparative results are shown in Figure 4(a,b) and Table 2.

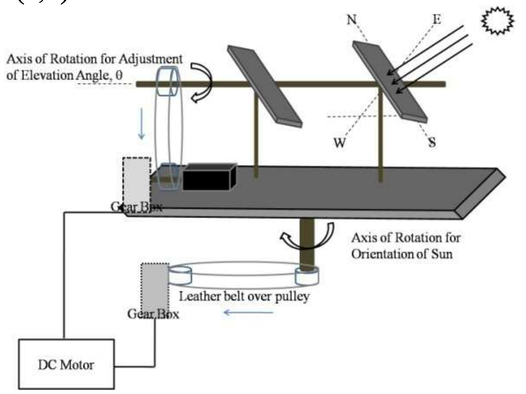

Figure 2: Schematic diagram of two axis solar tracking PV module

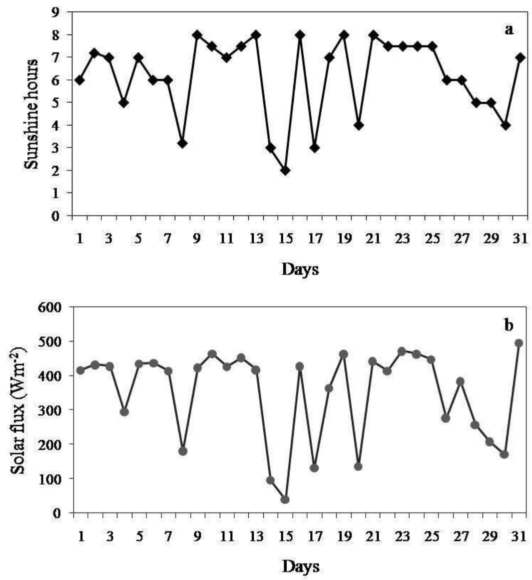

Figure 1: Daily variation in (a) sunshine hours and (b) total incoming solar flux; during Oct. 2012

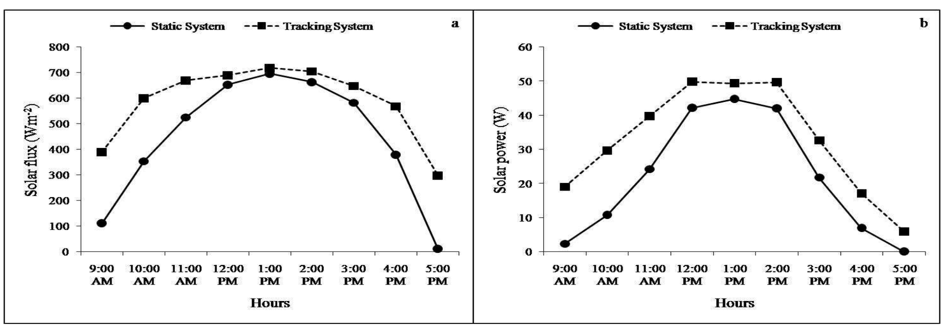

Figure 3: Comparison between static solar panel and solar tracking system

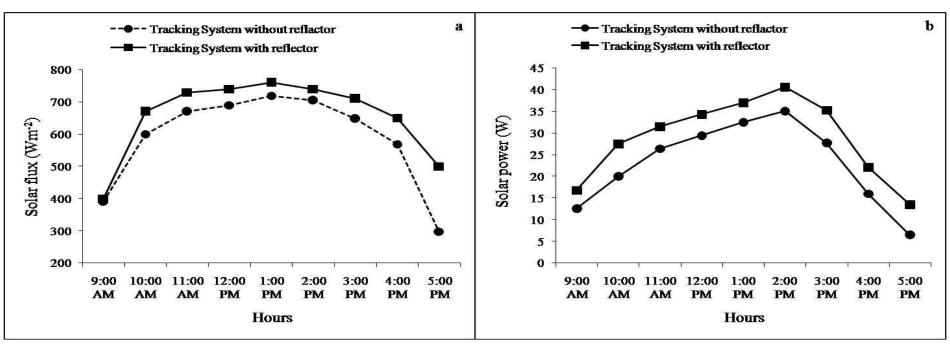

Figure 4: Comparison between solar tracking system without reflector and with reflector

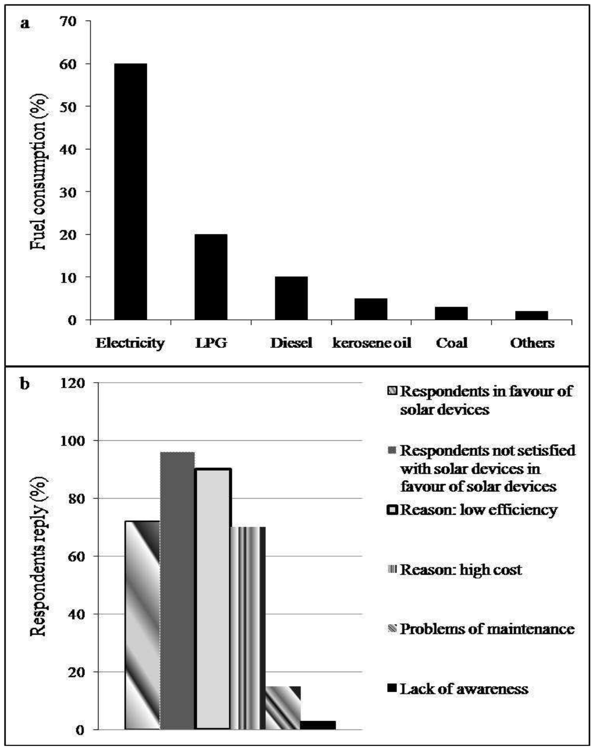

Figure 5: Respondent responses

Table 1: Reading data from solar panel during hardware testing

	Static System					Tracking System					
Time	**Solar Flux (Wm^{-2})**	**Voltage (V)**	**Current (A)**	**Power (W)**	**Efficiency (%)**	**Solar Flux (Wm^{-2})**	**Voltage (V)**	**Current (A)**	**Power (W)**	**Efficiency (%)**	**Gain (%)**
9:00 AM	112	6.5	0.36	2.3	5.7	390	8.3	2.3	19.1	13.3	134.3
10:00 AM	354	9	1.2	10.8	8.3	600	9.9	3	29.7	13.5	62.3
11:00 AM	525	11	2.2	24.2	12.6	670	11.7	3.2	37.4	15.2	21.2
12:00 PM	653	13.6	3.1	42.2	17.6	690	15	3.3	49.5	19.5	11.1
1:00 PM	696	14	3.2	44.8	17.5	719	15.1	3.3	49.8	18.9	7.7
2:00 PM	663	14	3	42.0	17.3	705	14.6	3.3	48.2	18.6	7.9
3:00 PM	582	13.6	1.6	21.8	10.2	648	13.6	2.4	32.6	13.7	34.7
4:00 PM	380	7	1	7.0	5.0	569	7.8	2.2	17.2	8.2	63.7
5:00 PM	12	1	0.1	0.1	2.3	298	3	2	6.0	5.5	141.6
Average	**442**	**10**	**1.8**	**22**	**10.7**	**588**	**11**	**2.8**	**32**	**14.1**	**53.8**

Table 2: Reading data from solar panel during hardware testing

	Tracking System without reflector					Tracking System with reflector					
Time	Solar Flux (Wm^{-2})	Voltage (V)	Current (A)	Power (W)	Efficiency (%)	Solar Flux (Wm^{-2})	Voltage (V)	Current (A)	Power (W)	Efficiency (%)	Gain (%)
9:00 AM	390	9	1.4	12.6	8.8	400	12	1.4	16.8	11.4	30
10:00 AM	600	10	2	20	9.1	670	12.5	2.2	27.5	11.2	23.1
11:00 AM	670	12	2.2	26.4	10.7	730	12.6	2.5	31.5	11.8	9.5
12:00 PM	690	12.8	2.3	29.4	11.6	740	12.7	2.7	34.3	12.6	8.6
1:00 PM	719	13	2.5	32.5	12.3	760	13.2	2.8	37	13.3	7.6
2:00 PM	705	13.5	2.6	35.1	13.6	740	14	2.9	40.6	14.9	10.2
3:00 PM	648	13.2	2.1	27.7	11.7	710	14.1	2.5	35.3	13.5	16.1
4:00 PM	569	10	1.6	16	7.7	650	13	1.7	22.1	9.3	20.9
5:00 PM	298	6.5	1	6.5	5.9	506	9	1.5	13.5	7.4	23.8
Average	**588**	**11.1**	**2**	**23**	**10.2**	**656**	**12.6**	**2.2**	**28**	**11.7**	**16.6**

Table 3: Statistical analysis in term of economic feasibility for solar panel having surface area 0.367 m^2

	Average solar flux (Wm^{-2})	Efficiency (%)	Production/hour (kW)	For five hours/month (kWh)	Saving/month @ 3.20Rs	Saving/year (Rs)
Static module	442	10.7	442×0.367×10.7 = 1.7	1.7×5×30 = 255	816	9792
Tracking module	586	14.1	586×0.367×14.1 = 3	3×5×30 = 450	1440	17280
Tracking module with reflector	586	16.5	586×0.367×16.5 = 3.6	3.6×5×30 = 525	1680	20160

4. ECONOMIC FEASIBILITY

We, use these results for evaluating the economic feasibility of a solar tracking PV module. The additional cost for the tracking mechanism, reflector and additional PV module may be the issue of great concern. The additional cost will be higher for larger PV modules due to the increase in structure weight and PV area. Study of fuels consumed in hotel sector revealed that electricity is the most common source of energy, followed by LPG and diesel (figure 5a). Other fuels to meet the energy demand include coal, kerosene etc. Fuels like wood, furnace oil, and solid fuel are also used as energy fuels in hotels. Survey suggests that about 72% respondents are in favour to install solar energy devices and other energy conservation measures to reduce their

electricity bill load. But, respondents put question mark on their output efficiency (figure 5b). Statistical analysis (Table 3) reveals that by using solar tracking PV module we can save amount of worth Rs 17280 per year. This amount is approximately double the amount of static PV module. For a solar tracker with reflector technology this amount may be much higher.

5. CONCLUSION

For more efficient 0use of solar energy all the solar devices should be sun tracker. The tracking system has a great importance especially in the morning and evening hours of the day. By using a solar tracking PV module we can increase power production by 45%. The power production further can be increase by 21% using the application of reflector technology. The proposed designed solar tracking mechanism would be valuable to the Engineering to develop a solar tracking technology. If this happens it will be the great success of our team to lead a step towards: “Explore, Harness and Conserve” Energy.

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